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APPLICATION OF LANDSAT-2
TO THE MANAGEMENT OF DELAWARE'S
MARINE AND WETLAND RESOURCES

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CONTRACT NAS5-20983

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GOODARD SPACE FLIGHT CENTER
GREENBELT, MD 20771

A. PROBLEMS

Of the six objectives indicated in Section B, numbers 2, 3 and 4 will be completed this year. However more work needs to be done on work related to objectives 1, 5 and 6. As outlined below, these three areas have yielded exceptionally good results, have very strong user interest, yet require additional time and money in order to bring the efforts to a proper conclusion. Therefore a proposal requesting a 12 month extension and additional funding for $19,704 was submitted to NASA on March 31, 1976. (Ref. 1)

B. ACCOMPLISHMENTS

1. General

Studies of the Delaware Bay region with LANDSATS-1-and-2 have so far produced useful results for all six objectives outlined in the work statement.

Objective 1. Monitoring the dispersion and movement of ocean dump plumes. (Work Statement Tasks 1, 2, 3 and 4).

2. Suspended sediment Concentration mapping (Work Statement Tasks 5, 6 and 7).

3. Current circulation and boundary charting for a model which predicts the movement of oil slicks (Work Statement Tasks 8, 9, 10 and 11).

4. Coastal land use and vegetation studies. (Work Statement Tasks 12, 13 and 14).

5. Comparison of training site and spectral signature (with atmospheric correction) techniques for classifying coastal land cover and environmental impact. (Work Statement Task 15).

6. Impact of Outer Continental Shelf development on the coastal zone of Delaware. (Work Statement Tasks 16, 17 and 18).

A detailed description of each objective is included in the proposal. Many of the results attained are presented in progress reports and recent

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publications. (Ref. 2, 3, 4, 5, 6 and 7). All of the problem areas shown above have been identified as being urgent by key federal, state or local user groups. The identified needs and support of these user groups, such as EPA, is the reason way we proposed to study these problems in the first place. Therefore many of these objectives directly support related investigations sponsored by these user groups.

2. Boundary Charting for Oil Slick Movement Prediction Model

A computer simulation model has been developed for tracing oil spills in the Delaware Bay. (NSF-RANN Grant) The model has two distinctive modes: drifting and spreading. The mechanism of drifting is based on the fact that oil on water drifts under the combined influence of water current, wind effect, and earth rotation. The physical processes governing the spreading of the slick are divided into three stage, the spreading involves the balance of viscous and inertial forces. In the third and final stage of the spreading, a turbulane diffusion model is employed. Based on these processes and the approximation of radial symmetry, the rate of spreading is computed.

The input requirements include the boundary conditions (the geometry and bottom topography), the tidal current, the wind condition, and the nature of the oil spill - viz., the size of the spill, location of the initial spill and the nature of the oil. Contemporary tidal current information and wind conditions in the Delaware Bay region are now being used as input.

The wind condition can be entered in either of two ways. It can be entered at finite time increments with known and predetermined values or with computed outcome for stochastic analysis of past wind records. The former way provides an oil tracking routine, and the latter input yields information on the probability of oil spill distributions.

The interactive nature of the model allows for information transfer between the computer and the users who may or may not be familiar with computer programming. The details of oil spill tracking are displayed on a Tektronix television-type screen. A number of output options are available.

In order to verify and improve the model, aircraft and boats were combined to track actual oil slicks under various conditions of wind, current, waves, etc. During these field verification exercises it became obvious that by capturing and holding oil slicks, frontal systems such as the ones described in Ref. 7, significantly influence the dynamic behavior of oil slicks in Delaware Bay. The tendency of oil slicks to line up along fronts during certain parts of the tidal cycle was illustrated by an oil spill which occurred on January 10, 1975, as a result of a lightering operation in the anchorage area. 0930 hours the spill consisted of four large slicks and numerous smaller ones almost randomly dispersed throughout the area. The wind was about 10 knots from the east-sourtheast. The flood tide cycle was coming to an end with a 0.9 knot current, as measured with current meters and the air-tracked small drogues. At this time no boundaries were observed. By 1100 hours the current had turned to the ebb direction with a velocity of 0.6 knots. Two convergent boundaries were clearly visible on either side of the oil slicks and were starting to attract some of the slicks. By 1500 hours most of the oil was aligned along the boundaries and stretched into two five-mile long slicks. If one wishes to modify the predictive model to include the effect of boundaries on oil slick behavior one must determine where in the bay boundaries form repeatedly and prevail over major portions of the tidal cycle.

In order to determine where in the bay fronts tend to form during different portions of the tidal cycle, thirty-six LANDSAT images of Delaware Bay were analyzed. The tidal conditions in each satellite

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image were matched to one of the twelve U. S. Coast and Geodetic Survey tidal current charts (Ref. 8), where each chart represents average current conditions in Delaware Bay during an one-hour segment of the tidal cycle. Thus an average of three satellite images were associated with each of the twelve current charts. As shown in Figure 1 and 2, the fronts discerned in each image were superimposed on the appropriate tidal current chart. The identification of fronts was based primarily on strong turbidity gradients or discontinuities. As discussed in a previous section, some of the fronts are likely to have foam lines, temperature gradients and salinity gradients associated with them. Foam lines, which can be mapped from aircraft, are too thin to be resolved by LANDSAT. Temperature and salinity gradient monitoring would require different sensors than those presently on LANDSAT. Two types of boundaries were distinguished - "strong" and "weak," depending on the magnitude of the turbidity gradient or discontininty. The strong boundaries not only contain strong gradients but also are likely to be convergent and exhibit considerable shear. The "weak" boundaries are either strong boundaries whose contrast has been degraded by atmospheric effects; or convergent boundaries observed during their formative or decaying stages; or divergent boundaries and, in a few cases, edges of river plumes.

To aid in the identification of turbidity gradients causes by boundaries, some of the LANDSAT images were enhanced by color density slicing and by digital analysis techniques. (Ref.)

The twelve charts containing current velocity and boundaries are presently being used to establish locations where boundaries tend to prevail. A subroutine is being developed for the oil slick movement model to handle oil slicks that enter these boundary-infested areas. The subroutine

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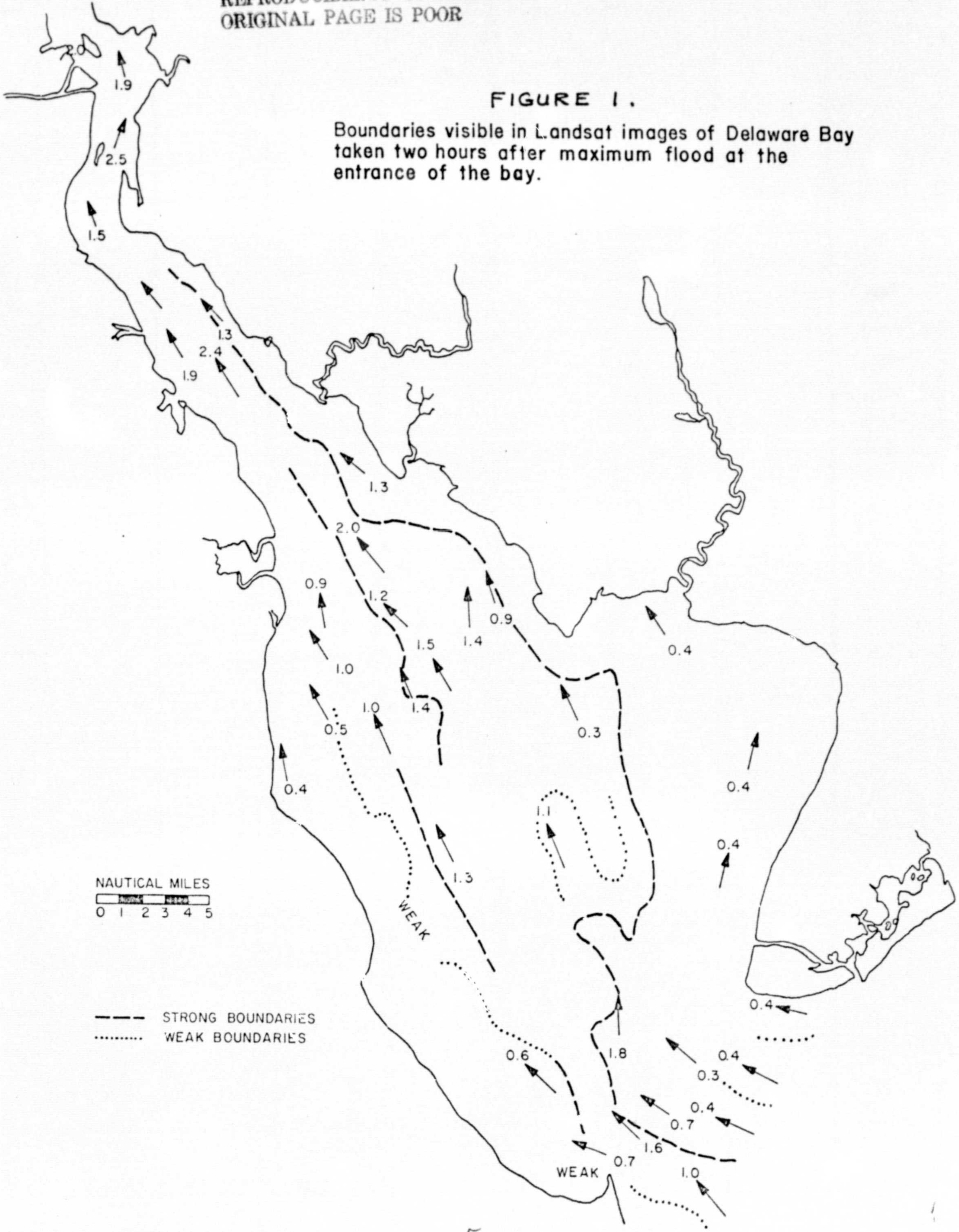
FIGURE 1.

Boundaries visible in Landsat images of Delaware Bay taken two hours after maximum flood at the entrance of the bay.



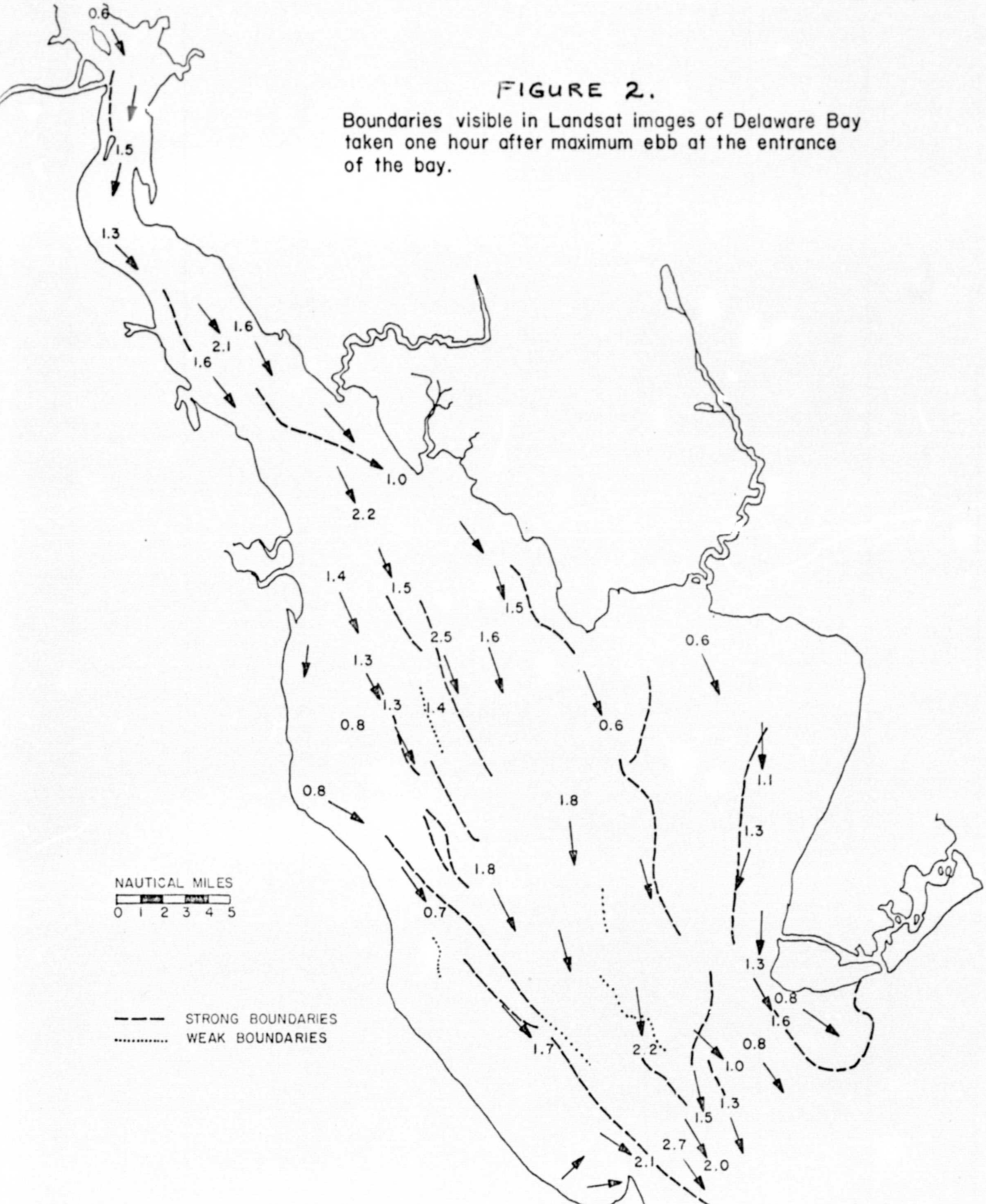


FIGURE 2.

Boundaries visible in Landsat images of Delaware Bay taken one hour after maximum ebb at the entrance of the bay.

will inculde the dynamic effects, such as shear currents, at a finer scale and in three dimensions. At the present time LANDSAT appears to offer the most effective means of identifying boundary-infested areas, i.e. where shear boundaries tend to form, how extensive they are, how long they prevail, how much they move about, and how strong and abrupt their gradients are.

3. An Assessment of the Possible Onshore Impact of Mid-Atlantic OCS Development

The objective of this study is to assess the probable land use impact of Mid-Atlantic OCS development on the Delaware coastal zone through the development of an empirical model. More specifically, it is designed to predict the types and possibly the locations of OCS related activity to be established along the Delaware coast.

An examination of OCS-related land use change in five sample sites has been completed. The overall project design is depicted in Figure 3. All of these sites have undergone OCS development over the past thirty years and each bears some similarity to the likely sites of development on the onshore OCS development in Delaware is being made based on these examinations.

Geographically the sample sites are located in three principal settings: 1) Kenai Peninsula, Alaska; 2) Cameron, Morgan City, and Venice, Louisiana; and 3) Santa Barbara, Ventura, and Carpinteria, California. Developmentally the sample sites fall into three corresponding categories: 1) Frontier development (Alaska); 2) Intensive development (Louisiana); and 3) Multiple-use conflict development (California). Each category and site presents an analog to Delaware's coast. None of these cases, however, duplicates exactly the conditions present along the Mid-Atlantic shoreline. (Figure 4)

For example, the frontier case in Alaska offers a good analog in that the scale of offshore development is similar to that which is expected along the Mid-Atlantic OCS. On the other hand Alaska suffers from dissimilar weather and climatic constraints. The most significant aspect of the Alaskan development with regards to Delaware has been the demonstration that exploratory drilling can be supported through remote centers; thereby delaying local support construction until the value of a drill site has been established.

In contrast to the Alaska case, Louisiana has undergone extensive offshore, nearshore, and onshore OCS development. It does, however, present an interesting analog in that the length of it's shoreline is nearly identical to that of the Mid-Atlantic coast. From this similarity it may be possible to derive clues as to the likely location of possible development along the Delaware coast.

Finally the California case, which has emerged through

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multiple-use conflicts, offers a good analog to Delaware. The intensity of operations is low there, as is planned for the Mid-Atlantic coast. The land use conflicts which have arisen, for example recreational vs. industrial, pose interesting examples of what could happen in Delaware.

It is important to note that the analysis of Mid-Atlantic OCS development is handicapped by one factor not intrinsic to any of the other cases. This factor is the multi-state boundary problem along the Mid-Atlantic coastline. In all of the other cases onshore support and development occurred in the adjacent state. In the case of Delaware, however, a facility could be located inland, easily accessible to the Delaware coast but within the state of Maryland. The facility would then be beyond the control of the state of Delaware.

The land use changes, indicative of onshore impact of OCS development, are being mapped at a scale of 1:24,000. Remote sensor and mapped data will provide the major land use map compilation inputs. For each sample site two land use maps are being constructed. The first is being compiled from data which pre-dates the advent of OCS development. The second will be compiled using the most recent data available. The land use change map will then be derived by comparing the first two land use maps. The areas that changed will be depicted by polygons, each with a code identifying from-what to-what the land use changed.

It is realized that not all land use changes can be construed as indicating impact of OCS development. There are, however, particular land use types whose appearance, when contemporaneous with OCS activity, do suggest such a correlation (Table 1). Conditions can also exist where the appearance of these "indicators" does not necessarily correspond to OCS development. In California, for example, onshore drilling existed years before the presence of offshore rigs. Although many facilities associated with onshore drilling were completed prior to the initiation of offshore activity, others have since been erected. While identification of structures is generally attainable via remote sensing techniques, the discrimination of functional associations of these structures does not necessarily follow. In complex cases such as these, alternative sources of data must be utilized. These sources could include state and local planning reports, reports from the state executive office, industrial reports, and even environmental newsletters and pamphlets. If, after an extensive literature search and correspondence, facility associations cannot be made, a field trip may be justified.

Once the land use changes resulting from OCS activity are delimited for each sample site, an analysis of their relationship to likely sites of parallel development in Delaware will be examined. Land use maps at a scale of 1:24,000 will then be compiled for these likely sites in Delaware using recent aerial photography. These maps can then serve as the pre-development base for monitoring OCS-induced land use changes in the future.

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TABLE 1 -- OFFSHORE SUPPORT PARAMETERS OF INTEREST

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1. Area allocated to activity i.e.:

    a. Storage tanks

    b. Storage sheds

    c. Piers or wharfs

    d. Platform fabrication

    e. Landing fields and heliports

    f. Marshalling areas (Rail, Truck, etc.).

2. Numbers of activity sites.

3. Types of industrial activities and location from MHWL:

    a. Petroleum-related (pipeline terminals, refineries, etc.)

    b. Petrochemical

    c. Steel fabrication

    d. Boat building and maintenance

    e. Power plants.

4. Growth of transportation networks and services:

    a. Road

    b. Canal

    c. Rail

    d. Pipeline right-of-way.

5. Land-use distribution:

    a. Open

    b. Agriculture

    c. Industrial Commerical

    d. Residential.

6. Type of activity development in relation to target area and density:

    a. Linear vs. radial

    b. Extent of water orientation.

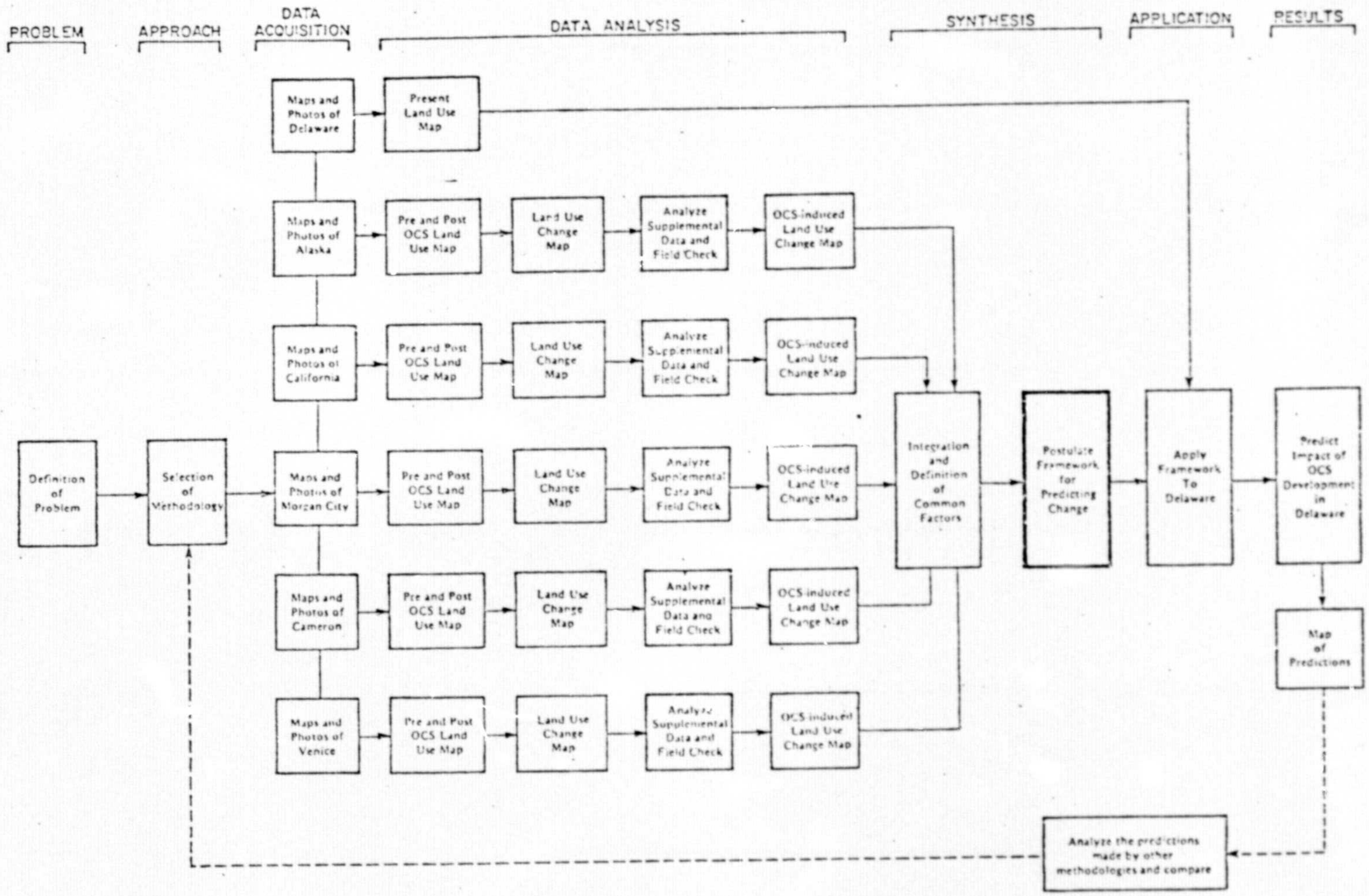

FIGURE 3.

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FIGURE 4.

TEST SITES -- AREAS OF OCS DEVELOPMENT

C. SIGNIFICANT RESULTS

Imagery foam LANDSAT-1-and-2 has been analyzed to determine the location, type and extent of fronts and boundaries in Delaware Bay as a function of tidal conditions. This information is being used to set up a subroutine for an oil slick movement prediction model.

D. PUBLICATIONS

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2. Klemas, V, Bartlett, D., Rogers, R., Coastal Zone Classification from Satellite Imagery. Photogrammetric Engineering and Remote Sensing, Journal of the American Society of Photogrammtry, Vol. 41, No. 3, April, 1975.

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7. Klemas, V., Davis, G., Wang, H., Whelan, W., Monitoring Estuarine Circulation and Ocean Waste Dispersion Using Integrated Satellite-Aircraft-Drogue Approach, International Conference on Environmental Sensing and Assessment, Las Vegas, September 14-19, 1975.

8. Klemas, V., Remote Sensing of Wetlands Vegetation and Estuarine Water Properties, Proceedings Third International Estuarine Research Conference, Galveston, October 6-9, 1975. (Invited paper).

9. Seven reports on significant result to NTIS.

E. RECOMMENDATIONS

Make more attempts to obtain LANDSAT MSS imagery of our test site in the high-gain mode to enhance water features (suspended sediment pattern, ocean waste disposal plumes, etc.).

Order NOAA/EDS not to send LANDSAT-2 prints and transparencies with excessive cloud cover and outside our test site.

F. FUNDS

On schedule for Objectives 2, 3 and 4. Insufficient for Objectives 1, 5 and 6, as explained in Section A. NOAA/EDS budget overexpended. USGS/ERSO budget underexpended.

G. DATA USE

All ordered LANDSAT-2 tapes have been received so far. They have been evaluated and are currently being analyzed.

Many of the LANDSAT-2 film products from NOAA/EDS Satellite Data Service Branch have excessive cloud cover or cover test sites adjacent to ours. This is part of the reason for the NOAA budget cost overrun.

H. AIRCRAFT DATA

Aircraft overflights have been on time and/or target. Some imagery has been received and more imagery is on order. Most of the aircraft data will be evaluated during the next four months.

I. PERSONNEL CHANGES

None.

J. REFERENCES

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2. Klemas, V.; Bartlett, D. S., and Rogers R.; Coastal zone classification from satellite imagery, P. E. and R. S., v. 41, 3, 1975.

3. Rogers, R; Peacock, K. and Shah, N. - A technique for correcting ERTS data for solar and atmospheric effects - 3rd ERTS Symp. and NASA SP-351, Goddard S.C., Greenbelt, Md. 1973.

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